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Case Study of Seagate

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Title: The Case study of Seagate Hard Disk Drive: The pioneer of technological disruptive innovation in Hard Disk Drive industry

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1 Introduction

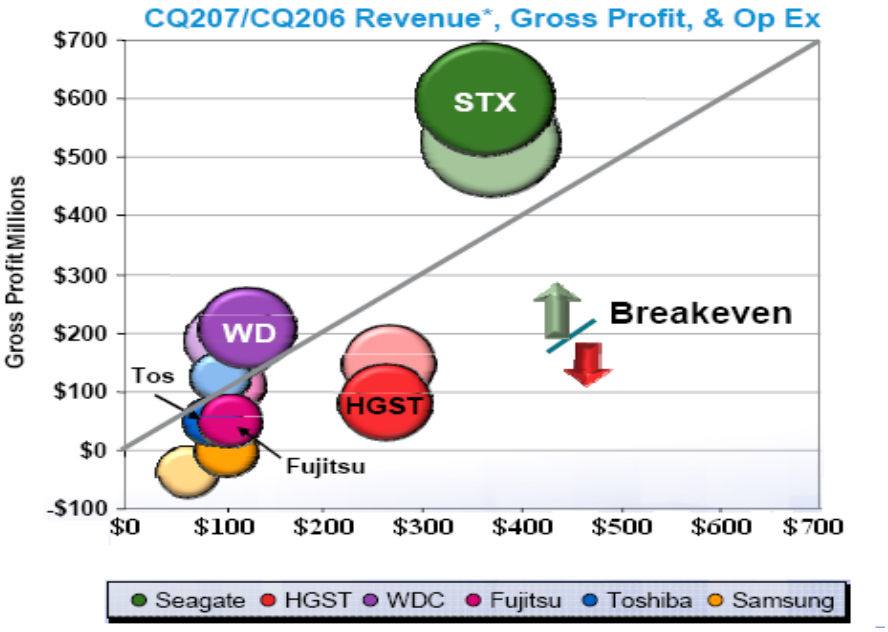
HDD industry is a fast-paced business, there were 2000 disc drive companies in the last 20 years, and now there are about seven or eight. So I recognized years ago that this was a burn-out type of industry. ----Tom Porter[1], 2000

As suggested by Tom Porter, many shakeouts happened in the hard disk drive industry because innovative product architectures readily crossed market segment boundaries, while the firm participating in the industry experienced considerable difficulty adopting these architectures, when such boundary-crossing occurred. However, as shown in Figure 1, among the very few firms that managed to survive and grow until today, Seagate is the largest and most profitable one. Seagate was also the only one out of over 50 do-novo startup firms that still survive today. How could Seagate succeed in the very fast-paced industry with significant pressure? Why Seagate but not other startup firms could compete with large incumbents firms and gained advantages? Based on the theoretical lens of disruptive innovation, we carried out a longitudinal case study of Seagate in retrospective.

A wide range of publications are available in journals and industrial reports to help us understand the nature of the industry and the strategies and actions of Seagate and its major competitors. The transparency of the Hard Disk Drive industry is significantly higher than most of the other industries. Our research relies on the industrial reports such as Trend Focus and Disk/Trend

[1] ex-CTO of Seagate, came in via Western Digital and before that, IBM.

which are highly reliable, thorough, and credible industry analysis that cover the changes of firms and their product specifications along the years. There are a large number of technology and management publications on hard disk drives at our disposal, contributing to our understanding of Seagate and its rise and fall since early 1980s. To name a few, “Magnetic Recording Technology: The First 100 Years”, “From Silicon Valley to Singapore: Location and competitive advantage in the hard disk drive industry”, and many academic papers in top journals (e.x. Chesbrough, 1999; Chesbrough and Kusunoki, 2001; Chesbrough, 2003; Christensen, 1993; Christensen, 1996; Christensen, 2002; Sahlman and Stevenson, 1985). Collectively, the data sources were summarized in Table 1.



Revenue shown in Bubble size

Source: Seagate Technology 2007 Analyst meeting---Sep, 7, 2007.

Figure 1 Relative Performance of HDD participants in 2007.

Table 1 Sources of the case study

TYPE	SOURCE NAME	DATE OF COLLECTION	SOURCE INFORMATION
Document	Seagate - Quantum: Encroachment Strategies Case Article	March, 2008	D:\case studies raw data\Seagate\SCHMIDT & VAN MIEGHEM -- SEAGATE - QUANTUM ENCROACHMENT STRATEGIES.htm
	The Innovator's Challenge: Understanding the Influence of Market Environment on Processes of Technology Development in the Rigid Hard Disk Drive industry	October, 2007	Clayton Christensen, Thesis for the degree of Doctor of Business Administration, Harvard University, 1992.
	The Innovator's dilemma, when new technologies cause great firms to fail	March, 2008	Clayton Christensen, Book, Harvard Business School Press, 1997. Chapter 1.
	From Silicon Valley to Singapore, Location and competitive advantage in the Hard Disk Drive industry	March, 2008	David Mckendrick, Richard F.Doner and Stephan Haggard, Standford University Press, 2000.
	Magnetic Recording Technology: The First 100 Years	January, 2008	Eric D. Daniel, C. Denis Mee and Mark H. Clark, IEEE Press, 1999.
	Disk Trend Reports From 1980 to 2000	May, 2008	Jim Porter, Disk/Trend Inc. We are greatly indebted to him for providing the reports.
	Trend Focus, Reports From 2000 to 2007	June, 2008	Mark Geenen, Trend Focus Inc. We are greatly indebted to him and his colleagues for providing the reports.
	Arrested development: the experience of European hard disk drive firms in comparison with US and Japanese firms	August, 2008	Chesbrough, H.W. 1999. **Evolutionary Economics**, 9: 287-329.
	The Modularity Trap: Innovation, Technology Phase Shifts and the Resulting Limits of Virtual	August, 2008	Chesbrough, H.W. and Kusunoki, K. 2001. **In Managing Industrial Knowledge: Creation, Transfer and Utilization**, by Nonaka I. and Teece

	Organizations.		D.J. Sage: 203-230.
	Environmental influences upon entry into new sub-markets Evidences from the worldwide hard disk drive industry conditionally	August, 2008	Chesbrough, H.W. 2003. **Research policy**, 32: 659-678.
	The rigid disk drive industry: A history of commercial and technological turbulence.	August, 2008	Christensen, C.M. 1993 **Business History Review**, **67**(4), 531-589.
	Capital Market Myopia	August, 2008	*Sahlman W.A. and Stevenson H.H. 1985.* **Journal of Business Venturing,** *1: 7-30.*
	Seagate Technology 2007 Analyst meeting	July, 2008	Seagate Technology Analyst Meeting slides provided by Seagate via field study
	Disruption, disintegration and the dissipation of differentiability	August, 2008	Christensen, C.M. 2002. **Industrial and Corporate Change**, 11(5): 955-993.
	Disruptiveness of Innovations: Measurement and Assessment of Reliability and Validity		Govindarajan V. and Kopalle P.K. 2006, **Strategic Management Journal**, 27: 189-199.
Interview	Interview of Prof Mark Kryder, Ex-Head of Seagate Research	Nov-Dec, 2007	Please see the appendix I for the interview transcript.
	Interview of Mr Say Kwee Teck, VP Engineering and R&D Director Singapore	Dec, 2007	Please see the appendix II for the interview transcript.
	Interview of Mr Djohni Chandra, Executive Director, Singapore	Jan, 2008	Please see the appendix III for the interview transcript.

2 A Series of disruptive innovations in Hard Disk Drives (HDD)

In this section, the disruptive nature of each generation of Hard Disk Drive has been carefully examined. Govindarajan and Kopalle (2006) performed a series of analyses to establish the reliability and validity of the disruptiveness scale. Their measure was further supported by the reliability measures, exploratory factor analysis, confirmatory factor analysis and statistical tests. According to their measurement, a disruptive innovation should be (i) inferior on the attributes that mainstream customers value; (ii) offer new values propositions to attract a new customer segment or the more price sensitive mainstream market (iii) sold at a lower price and (iv) the market penetration goes from niche to mainstream. Based on their definition, our findings demonstrated the disruptiveness of 8-inch, 5.25-inch, 3.5-inch, and 2.5-inch to their previous generation, and non-disruptiveness of 1.8-inch, 1.3-inch and 1-inch. The disruptive process of 8-inch to 14-inch was elaborated and a clear comparison of performances and cost was illustrated in Table 2.

Until the late 1970s, 14 inch drives were the only architectures available, and nearly all were sold to mainframe computer manufacturers. The growth in capacity which the disk drive industry provided in the 14-inch architecture grew faster than the growth demanded by the mainstream mainframe computer market (150-200MB), taking the 14-inch architecture into higher-end scientific and supercomputers. Between 1978 and 1980, 5 do-novo startup firms[2] entered the industry with families of 8 inch drive with 10-40 MB capacity. These drives were of no interest to mainframe computer manufacturers, which at that time were demanding drives with 300-400MB capacity. These 8 inch entrants therefore sold their small, low-capacity drives into a new application—minicomputers. Their customers-Wang, DEC, Data General, Prime and HP—were different firms than those which manufactured mainframes, and their customers—often engineering organizations-tended to use software which was substantially different than programs used by mainframe computer users. This was a different system of nested architectures. Initially, although the cost per megabyte of capacity of 8-inch drives was higher than that of 14-inch products, the total cost of 8 inch unit was cheaper than 14 inch unit (Table 2).

[2] These 5 startup firms were Shugart Associates, International Memories, Micropolis, Priam and Quantum.

Once 8 inch drive manufacturers had found a “home” market in minicomputer market, they found they could increase the capacity of their products at 46% per year, a much faster rate than that demanded by their original minicomputer market. By mid-1980s, 8 inch drive makers were able to provide capacities required for lower-end mainframe computers. With complementary advantages such as less mechanical vibration and smaller size, 8 inch drives substituted for 14 inch drives in the mainframe computer market within 4 years. The market penetration went from niche market of minicomputer to mainstream market of mainframe.

As 8 inch drives penetrated the mainframe market, many established independent manufacturers of 14 inch drive began to fail. Two thirds of these manufactures never introduced an 8 inch drive. The one-third of the 14 inch manufacturers which did introduce 8-inch drives did so with about 2 years lag behind the leading entrant manufactures.

Table 2 Performances, cost and application comparison between 14 inch and 8 inch HDD

When the first 8 inch HDD was introduced in 1978.	**14 inch Hard Disk Drives**	**8 inch Hard Disk Drives**	**Comparison**
Capacity	300~400MB	10~40MB	8” inferior
Average positioning time(msec), fastest	25	27	8” inferior
Average rotational delay (msec)	9.6	6.9	8” superior
Average access time(msec)	30.1	36.6	8” inferior
Data transfer rate(Kbytes/sec)	1859	1031	8” inferior
Size	101.6 mm x 25.4 mm x 146 mm	241.3 mm x 117.5 mm x 362 mm	8” superior
Cost	US $6400	US$2700	8” superior
Application	Mainframe as mainstream	Minicomputer as niche market	

In the same vein, each generation was subsequently examined, and our findings has shown that apart from 8 inch drive, 5.25-inch, 3.5-inch and 2.5-inch drives were all disruptive compared to their previous generation, because their major performances in capacity, average access time and data transfer rate were all inferior, but they proposed new values in size and weight, with much cheaper unit cost. The penetration went from niche market to mainstream (Table 3, 4 and 5).

Table 3 Performances, cost and application comparison between 8 inch and 5.25 inch HDD

When the first 5.25 inch HDD was introduced in 1980.	**8 inch Hard Disk Drives**	**5.25 inch Hard Disk Drives**	**Comparison**
Capacity	40~300MB	5~10MB	5.25” inferior
Average positioning time(msec)	27	170	5.25” inferior
Average rotational delay (msec)	6.8	8.3	5.25” inferior
Average access time(msec)	36.6	178.3	5.25” inferior
Data transfer rate(Kbytes/sec)	1031	625	5.25” inferior
Size	241.3 mm x 117.5 mm x 362 mm	146.1 mm x 41.4 mm x 203 mm	5.25” superior
Cost	US$ 1600	US$ 1200	5.25” superior
Application	Minicomputer as mainstream	Desktop as niche market	

Table 4 Performances, cost and application comparison between 5.25 inch and 3.5 inch HDD

When the first 3.5 inch HDD was introduced in 1986.	**5.25 inch Hard Disk Drives**	**3.5 inch Hard Disk Drives**	**Comparison**
Capacity	80MB onwards	40MB	3.5” inferior
Average positioning time(msec)	28	29	3.5” inferior
Average rotational delay (msec)	8.3	8.3	3.5” inferior
Average access time(msec)	33.4	37.3	3.5” inferior
Data transfer rate(Kbytes/sec)	1250	1000	3.5” inferior
Size	146.1 mm x 41.4 mm x 203 mm	101.6 mm x 25.4 mm x 146 mm	3.5” superior
Cost	US $1695	US $500	3.5” superior
Application	Desktop as mainstream	Laptop as niche market	

Table 5 Performances, cost and application comparison between 3.5 inch and 2.5 inch HDD

When the first 2.5 inch HDD was introduced in 1988.	**3.5 inch Hard Disk Drives**	**2.5 inch Hard Disk Drives**	**Comparison**
Capacity	20~300MB	20MB	2.5” inferior
Average positioning time(msec)	20	28	2.5” inferior
Average rotational delay (msec)	8.3	8.9	2.5” inferior
Average access time(msec)	28.3~73.3	36.9	2.5” inferior
Data transfer rate(Kbytes/sec)	625~937.5	625	2.5” inferior
Size	101.6 mm x 25.4 mm x 146 mm	69.85 mm x 9.5–15mm mm x 100 mm	2.5” superior
Cost	US$230~3460	US$230.8	2.5” superior
Application	Laptop as mainstream	Consumer Electronics as niche market	

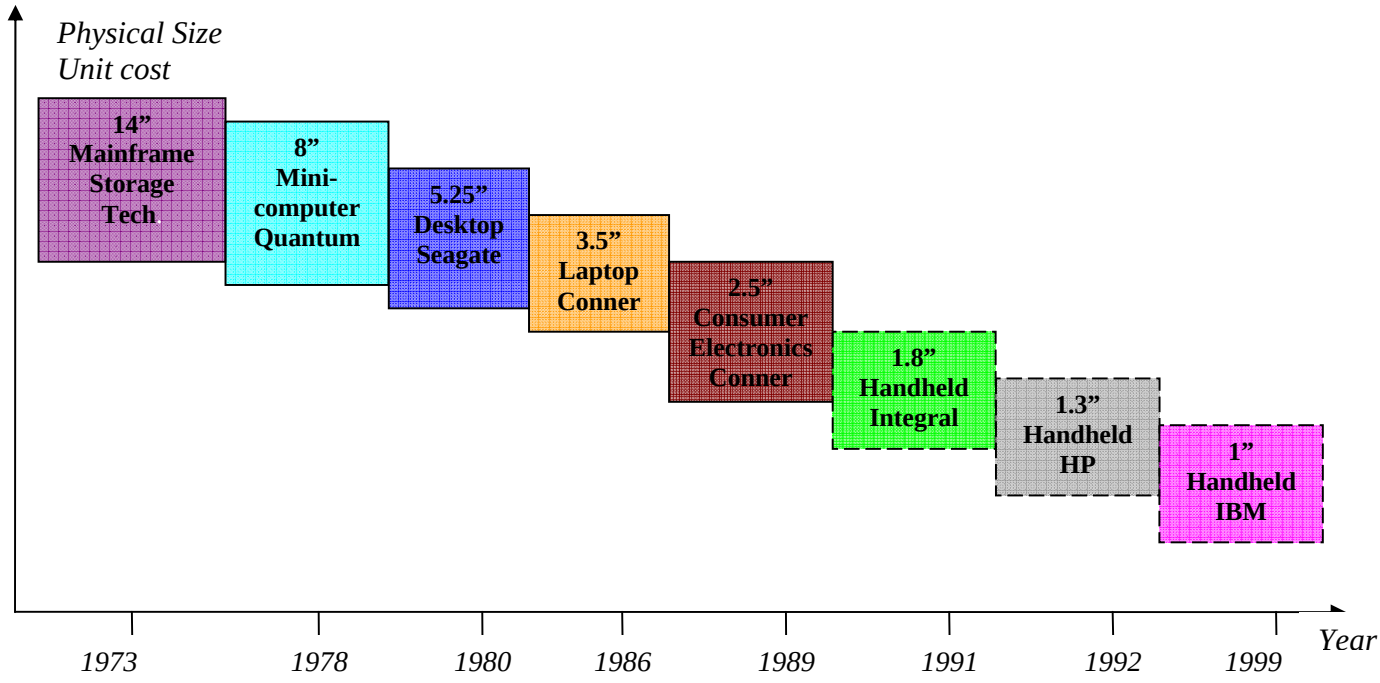


Figure 2 The disk drive market had a new leader almost every generation

3 Findings on Seagate's strategies and fluctuations during these generations

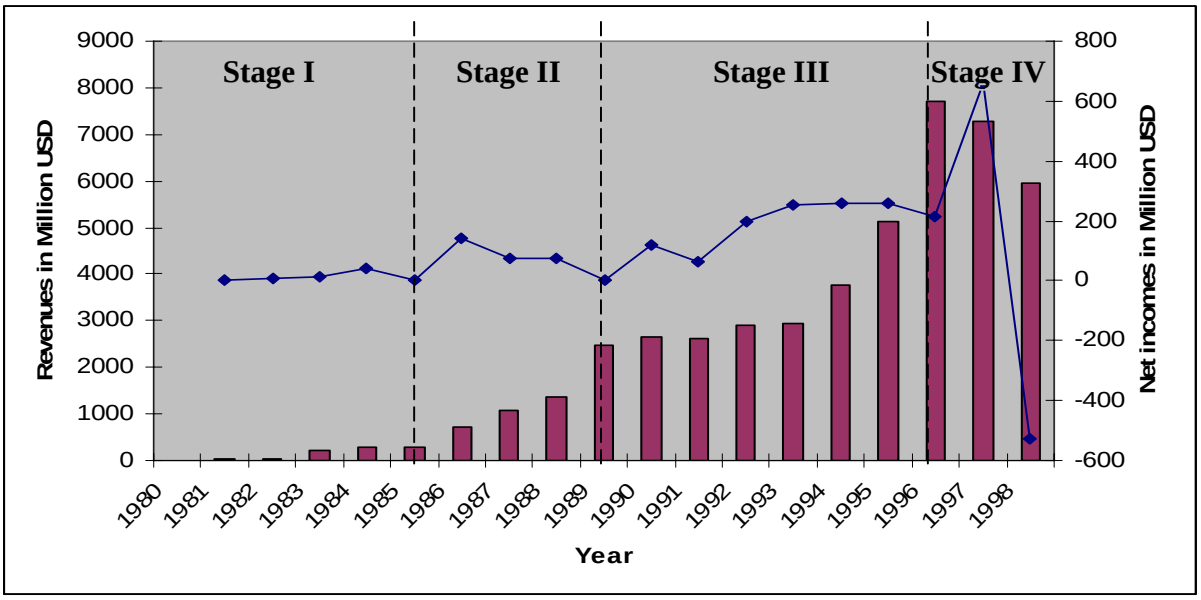


Figure 3 Seagate's Revenues and Net Income from Disks along the years

Source: Disk/Trend reports from 1980 to 1999

Our discussion of Seagate's strategies and fluctuations during product generations is divided into 5 stages:

- Stage I, Seagate was the definitive model for disk drive startup and the pioneer of 5.25 inch drive from1980 to 1985;
- Stage II, its leadership was disrupted by entrant firms when 3.5 inch emerged from 1986 to 1989; Stage III, Seagate started to emphasize on new product development and business expansion when it was the advent of 2.5 inch drive from 1990 to 1997;
- Stage IV, Seagate changed its major philosophy from technology follower to technology leader from1997 to 2000;
- Stage V, Seagate devoted significant efforts on 1 inch drives when the new application of small factors in CE markets was booming from 2000 to 2006;
- Stage VI, Seagate has full confidence in future HDD markets when they are well prepared with its own hybrid HDD and flash memory from 2007 onwards.

Stage I--Definitive model for disk drive startup---Pioneer of 5.25 inch drive---1980 to 1985.

Seagate Technology pioneered the 5.25 inch drive in 1980. Their capacities of 5 and 10 MB were of no interest to minicomputer manufacturers, who were demanding drives of 40 and 60 MB from their suppliers. Seagate has to pioneer new applications for their products by reconfiguring conventional Winchester technology into a package size that can compete with 5.25" floppy disk. The timing for the introduction of a 5.25" was perfect, catching the wave of desktop computers. The use of hard drives was established in the desktop PC applications where small size, light weight, us of internal power supply and low cost unit were highly valued. Gradually, the capacity was increased to the level that good enough for minicomputer and even mainframe markets, the disruption happened and 5.25" manufacturers became the new generation leaders.

Compared with other 5.25" producers, Seagate was extremely successful in establishing low-cost, high-quality manufacturing capacity, and in improving the speed and reliability of its 5.25 inch drives. The initial commitment to a production facility capable of extremely high volume levels made it possible to press for a large market share from the beginning. The establishment of an extensive marketing campaign and the early success in obtaining licensing agreements from

major firms as Texas Instruments and Cii-Honeywell Bull created a stampede in the industry to recognize the Seagate drive and interface ST506 and ST412 as defacto standards. In 1982, as a 3 year old HDD startup, Seagate began to assemble HDD components in Singapore, becoming the first firm in the industry to do so. At the time, its main competition was the minifloppy, an inexpensive data storage device that contributed to the explosion in demand for personal computers. Because potential customers were extremely sensitive to price, Seagate would have to build its new drive cheaply to capture a larger share of the emergent data storage business. The small company won contracts from IBM to supply disk drives for the IBM PC-2 and later PC/XT, but IBM was a demanding, even rentless, customers. Although competition in the industry was not yet as serve as it would become when more firms entered, Seagate knew that IBM and other computer manufacturers would press relentlessly for lower disk drive prices in exchange for the promise of future orders for the rapidly growing PC market. Seagate made a bold decision. Not only did it go abroad, but by 1984 it had shifted almost all disk drive assembly to plants it owned and operated in Singapore. In doing so, the company set in motion a dynamic that, within six years, transformed Singapore into the world's largest HDD assembler. Seagate developed and used its Southeast Asian platform to become the world's largest disk drive producer; the largest private employer in Singapore, Thailand and Malaysia; and China's largest exporter. Riding the wave of burgeoning personal computer sales through the early 1980s, Seagate grew to over 1 billion in revenues (prior to acquiring CDC), cumulatively shipping over six times as many drives in its product category as its next largest competitor. Naturally, Seagate became the definitive model for startup firms and the world's largest producer of 5.25-inch disk drives, with three-fourths of the company's shipments going to IBM.

However, in mid-1984 the computer industry entered a slump, and the average price for a wholesale ten-megabyte disk drive fell from $430 to $320 in a matter of days. A number of factors contributed to the situation, including a slowing in the growth of personal computer sales, industry wide falling prices, a glut of disk drive competitors, and rising costs of producing the new generation of drives. Diminished growth of personal computer sales came just as the disk-drive companies were squeezing the last profits from their older product lines. These difficulties were intensified for Seagate, with its reliance on IBM's business, when that company reduced

orders and began demanding lower prices. Thus, Seagate's sales dropped since 1984 and the annual sales declined 38 percent in 1985.

Seagate also sought to diversify its clientele in order to be less vulnerable to fluctuations in demand. Seagate began marketing more to value-added resellers (VARs), dealers that package stripped-down computer components and software and resell them as specialized systems. By 1987 such dealers came to represent 47 percent of Seagate's clients, up from zero in 1983, while sales to IBM fell to 24 percent. In that year a deal was also signed to supply drives to Hewlett-Packard, among other new personal computer makers. To expand sales internationally, Seagate set up a European headquarters in Versailles, France, in 1987.

Stage II--Dethronement of leadership-- Emergence of 3.5 inch --1986 to 1989.

Seagate's concentration on efficient production, while allowing technological innovation to take a back seat, made it vulnerable to the boom and bust cycles of the rapidly changing high technology industry. In 1987 computer manufacturers started demanding the smaller 3.5-inch drives earlier than anticipated. Market was seized by Conner Peripherals and Quantum; Seagate's share never exceeded 4% until 1989.

As a leading manufacturer, Seagate was not oblivious to the coming of the 3.5 inch form factor. By early 1985, less than one year after the first 3.5 inch drive was introduced by Rodime and 2 years before Conner peripherals started shipping its product, Seagate engineers had developed working 3.5 inch prototype drives. Their development had actually been instigated at the request of their largest customer, IBM. When IBM evaluated the 3.5 inch drive and understood their capacities were limited to 10 to 20MB, the product planners decided to go with next generation 5.25 inch drives instead. Having been abandoned by IBM, Seagate subsequently worked to sell the 3.5 inch drives to other customers. But the customers to who the 3.5 inch were shown were also manufactures of full-sized desktop computer systems. Not surprisingly, they showed little interest in the smaller drive, because the 3.5 inch architecture could only provide 20MB. The fact that Seagate's dominant immediate customers were distributors and value-added resellers, rather than OEM computer makers, seems to have intensified the cognitive inertia. In response to these

lukewarm reviews from customers, Seagate's program manager lowered his 3.5 inch sales estimates and the firm's executives subsequently shelved the 3.5 inch program. "*We needed a new model, which could become the next ST412, which at the time was generating $300 million per year in revenues. The 3.5 inch product just did not fit the bill.*" Recalled by a Seagate program manager.

However, when 3.5 inch form factor was becoming firmly established in portable and laptop applications in the 1984-1989 period, Seagate had in no way lost it ability to innovate. It was highly responsive to its own customers. On one hand, they increased their drives' capacity at 30% per year, perfectly match with market demand at that time. It introduced new models of 5.25 inch drives at an accelerated rate. During this period, Seagate announced new products which employed most of the available new component technologies—including thin film disks, voice coil actuators, RLL codes and embedded SCSI interfaces (Table 6). On the other hand, Seagate began to ship 3.5 inch drives in early 1988, when 3.5 inch drives began to pack the capacity required in the desktop market. Nevertheless, until 1991, almost all of Seagate's 3.5 inch products were sold to its primary customers that were desktop computer manufacturers, and many of its 3.5 inch drives continued to be shipped with frames permitting them to be mounted in XT and AT-class computers designed to accommodate 5.25 inch drives.

Table 6 Indicator of the Pace of Seagate Engineering Activity within the 5.25 inch drives

	New model announced	New models as % of models offered in prior year	% of new models equipped with Thin Film Head	Application of Embedded SCSI interface	Application of RLL codes
1984	3	50%	0		
1985	4	57%	25%	X	
1986	7	78%	71%		X
1987	15	115%	100%		

Source: Christensen C.M., Thesis, pp145.

The projected materials costs for a new architecture were almost always a major consideration for established firms evaluating whether or not to initiate development of a new architecture. However, the established manufacturers showed a strong and repeated initial tendency to overestimate the materials and component costs of new architectures. In fact, the enormous unit volumes in the minicomputer and personal and portable PC markets relative to earlier ones, material costs in each successive architecture were substantially lower than which established firms had projected. This was particularly true for Seagate. According to former employees interviewed[3], the personal conviction of engineering VP Doug mahon is that materials costs of the 3.5 inch drive could never approach those of 5.25 inch design was a major reason why Seagate entered 3.5 inch fray so late. However, because of the enormous unit volumes in the desktop PC markets relative to earlier minicomputer market, materials costs was substantially lower than those which established firms had projected.

The belated introduction of new 3.5 inch drives and over focus on existing desktop PC customers made Seagate's profits decline by 39 percent during this product transition period in the second half of 1987, and profits remained low into 1988. Seagate introduced six models of its first 3.5-inch drives that spring, although 5.25-inch drives continued to dominate its sales. The company had added 32,000 square feet to its Singapore plant, where the 3.5-inch disk drives were made. Meanwhile, it expanded operations in Thailand beyond the manufacture of components and sub-assembling to include the complete assembly process and testing of disk drives. More significantly, Seagate began investing greater amounts on research and development in 1987, double the amount of the previous year, by issuing $250 million in debentures. The company established a new research and development facility in Boulder, Colorado, in addition to the one at its headquarters in Scotts Valley.

The market's growth was less than anticipated, however, and revenue for fiscal 1988 declined 50 percent from the previous year, while inventories of 5.25-inch disks piled up. Seagate blamed the problem on industry-wide overproduction, while Shugart moved quickly to lay off nearly 2,200 employees in Singapore and the United States. The company barely stayed in the black for fiscal 1989.

[3] This is an indirect interview, quoted from Christensen C.M. thesis, pp125.

Seagate also actively seek other growth opportunities to compensate the loss from 3.5 inch drives. Firstly, since ups and downs in the demand for the personal computer market were a serious concern, Seagate's next move was to gain entry into the market for the high capacity drives used in mainframes, by purchasing Control Data's disk-drive subsidiary, Imprimis, in June 1989. The $450 million acquisition nearly doubled Seagate's sales, to $2.4 billion for fiscal 1990, larger than all its U.S. competitors--Conner Peripherals, Maxtor, Micropolis, and Quantum--combined. Seagate also had an edge on its competitors in its ability to provide consistently lower priced products, because the company manufactured its own disk drive components. In plants throughout the United States and in Asia, Seagate turned out motors, precision recording heads, and other parts. While the company built many of these factories itself, key component suppliers were also acquired by Seagate. In 1987 the company purchased Integrated Power Semiconductors, Ltd. of Scotland--a longtime Seagate supplier--and Aeon, a Brea, California-based producer of substrates to make thin film magnetic recording media.

Stage III—Emphasis on new products and business expansion--Advent of 2.5 inch drive -- 1990 to 1997

As a technology follower, Seagate continued to lag behind the competition when it came to introducing new technology. "*Seagate has never been that interested in getting products out of the lab first. We wait until we've squeezed every penny of cost out of a product before we bring it to market*" Shugart explained in *Forbes* in 1991, "*But the product cycles are getting shorter and shorter. Now we can't afford to wait. The latest product on the market was a 2.5-inch disk drive for laptop and notebook computers. Seagate introduced the drive in November 1990, only five months behind competitor Conner Peripherals, as compared with a delay of a year for the 3.5-inch drives."*

In late 1991, the company made key changes in executive management in an attempt to reassert product leadership and was successful in establishing an aggressive product development program. Mitchell's emphasis on high volume manufacturing over product innovation was one of the points of contention that led him to resign under pressure from the board in September 1991. Shugart then reasserted his role in running the company by giving up his position as chairman and assuming the posts of president and chief operating officer vacated by Mitchell. Gary Filler,

former vice-chairman, replaced Shugart as chairman. This change in management came on the heels of a disappointing year, with the layoff of another 1,650 workers and revenues down 42 percent.

Firmly in charge again, Shugart pursued a strategy of turning out new products as soon as they were designed. He also began focusing on higher profit margins and specific markets, contrary to Mitchell's goal of general large-volume sales. One of Shugart's first products in this regard was the 1480 disk drive introduced at the end of 1991. This 425-megabyte, 3.5-inch drive was successfully targeted at the high-end workstation and minicomputer markets, where profit margins were greater. Seagate beat the competition by introducing the product first, then continuing to outsell its rivals.

Seagate's profits rebounded beyond expectations in early 1992 as sales of lower priced, high-end personal computers took off amid vendor price wars. At the same time, Seagate also benefited from the current PC owner trend toward buying new higher capacity drives to run more powerful programs. The company's large market share ensured that such upswings in personal computer demand would have a definite effect on its sales.

In early 1993 Seagate invested $65 million in a factory in Londonderry, Northern Ireland, which doubled its capacity to produce a key part used in its hard drives. In addition, Seagate acquired a 25 percent stake in the Sundisk Corporation--another manufacturer of computer data storage products--and together the two companies produced data storage systems for portable computers and other hand-held electronic devices. In April of that year Seagate signed an agreement with Corning, the glass manufacturer, to provide a new glass-ceramic compound for use in disks. The new material allowed Seagate to reduce the distance between a disk and its magnetic read-write head, which enabled a higher capacity for data.

Disk drive makers hit a slump in 1993 due to rapidly declining prices, including Seagate. Seagate began acquiring software companies in 1994 to establish a position in data-retrieval software. It acquired software developers Palindrome Corporation of Napierville, Crystal Computer Services Inc., Frye Computer Systems, NetLabs Inc., and Network Computing Inc., and invested in

Dragon Systems Inc.. The company was investing in technologies and companies that would be significant for data management in the future.

In September 1995 Seagate announced it would acquire competitor Conner Peripherals in a deal valued at $1.04 billion. Conner not only manufactured disk and tape drives, it owned software subsidiary Arcada Software. After experiencing component shortages, price pressures, and significant losses, Conner agreed to a merger with Seagate. The deal was completed in February 1996. Together, Seagate and Conner accounted for about 33 percent of all hard-drive units sold in 1995, making the combined company the market-share leader ahead of Quantum Corporation.

In February 1996 Seagate officially formed a new software group, the Seagate Software Storage Management Group, by combining the operations of Palindrome Corporation and Arcada Software. The division became Seagate Software, Inc., later in 1996 and was headquartered in Arcada's home of Lake Mary, Florida. During the year Seagate continued to acquire software companies, including OnDemand Software Inc. for $13 million and Calypso Software Systems for $13 million. Calypso specialized in enterprise systems management software.

Seagate has grown significantly in hard disk drives business and the expansion in software markets by a number of successful M&A. However, the initial deployment of 2.5 inch drives in notebook computers did not bring substantial profits to either Seagate or to other leading players in the industry. Argued by Christensen, the transition from 3.5 inch to 2.5 inch was sustaining in the sense that the mainstream customers were the same, laptops and notebooks looked similar, not totally a different market segment. The transition was initiated by established companies such as Conner Peripherals, and entrants were the followers. In fact, 2.5 inch drives did not progress significant in terms of market demands and profit generators until the Consumer Electronics market started to boom around 2000.

Stage IV--From technology follower to technology leader -- 1997 to 2000

Seagate's financial results worsened significantly in fiscal 1998. Seagate reported a net loss of $530 million on declining revenues. The poor results were due in part to Seagate losing significant market share in the server market, which accounted for about half of the company's

revenues. Weak demand for personal computers and lower disk drive prices also impacted the company's earnings. In July Shugart was removed by the board of directors and subsequently resigned his position on the board. Luczo took over as president and chief executive officer. William Watkins was subsequently promoted to chief operating officer.

Among the problems facing the company were integrating recently acquired Conner Peripherals and speeding up the time it took to bring products to market. The Speed to market is of great importance when the acceleration in the areal density growth rate of hard drives was taking off in the late 1990s. Up until about 1991 the areal density growth rate was about 25% per year, which meant that a product lasted about 2 years. In 1991, IBM announced that henceforth the areal density growth rate would be 60% per year. This initially shocked the industry, but then competition actually caused the areal density growth rate to increase to over 100% per year. With an areal density growth rate of 100% per year, a product had to be replaced in about 6 months. With a product life cycle of two years, as in the 1980s, if a company were a few months late in introducing a new product, but produced a lower cost/better product, it could do very well on the backend of the product cycle. Hence, because Seagate had low-cost manufacturing capability, its close-follower strategy was quite successful and the company grew to become the largest maker of disk drives. However, with an areal density growth rate of 100% and a product life-cycle of 6 months, if you were 2-3 months late to market, the OEM's who were your customers weren't interested in even qualifying your product, because they were already looking ahead to the next product. This was the situation in 1997 when Seagate decided to change their strategy from being a close follower on technology to being the technology leader. (With the close follower strategy and the short product life cycle, Seagate was not doing well in the 2.5 inch business in 1997. The CTO Tom Porter believed that the only way to compete in the 2.5 inch business at that time was to have the leading technology.) In order to change the position as a technology leader rather than a quick follower, Tom decided to cancel all work on 2.5 inch drives at Seagate and use the money instead to invest in Advanced Concepts and Seagate Research. Tom asked Nigel Macleod to start the Advanced Concepts Laboratory, which had the mission of looking 2-5 years out and subsequently hired Prof Mark Kryder to start Seagate

Research[4], with the mission of looking 4-10 years in the future. Prior to that, drive development projects in Seagate started about 2 years ahead of product shipment. Together, they focused a great amount of attention on developing advanced technology and moving it into Seagate products. . For examples, they invested billions of dollars in the Data Storage Systems Center at Carnegie Mellon University, and we also have plenty of research collaborations with Research Institutes such as IMRE in Singapore. In a matter of a few years, under Tom's leadership, Seagate became the technology leader in the industry.

For fiscal 1999, both revenues and net income were recovered from previous year. Seagate improved its profitability in spite of price erosion on disk drive products through extensive cost-cutting and restructuring. During the fiscal year Seagate reduced its workforce from 87,000 to 82,000, of which some 65,000 were employed in Seagate's Far East operations. By the end of 1999 the company's workforce had been reduced to about 71,500 people.

At the end of the first quarter of 2000 Seagate became a privately held company. According to published reports, Seagate decided to go private to get away from the scrutiny of Wall Street investors. Under the terms of the deal, Veritas would acquire all of the Veritas Software shares held by Seagate, while the investor group would acquire Seagate's operating businesses for approximately $2 billion in cash in what was described as a management buyout. The investor group included members of Seagate's management team as well as other investors. As a private company, Seagate would be able to better focus on strengthening its core storage business. Company executives were more comfortable with their new partners' long-term views, as opposed to Wall Street's shorter-term expectations. Seagate planned to continue to implement its advanced manufacturing technologies, seek operational efficiencies, and position the company to take advantage of increased demand for storage-related technologies and products across multiple markets.

[4] Seagate Research has roughly 100 PhD's working there. It is a very diverse group, coming from 24 different countries and 65 different universities, the last that I knew. The total number of scientists and engineers (PhD's and not) was about 130 the last that I knew. They were generating 50-100 patents per year and a similar number of publications. Seagate Research collaborates with universities all over the world including the Data Storage Institute in Singapore and the National University of Singapore.

Stage V—significant efforts on 1 inch drives-- New application of small factors in CE markets --- 2000 to 2006

Seagate was not very active in the 1990s on the development of 2.5 inch drive because the profits margins were too limited. At that time, portable PC was not a large market segment, it is not until this year that mobile PCs have shipments that surpass the desktop PCs. Hence, the 2.5 inch drives, only in Portable PC application, has a very limited market shares compared with other form factors. Furthermore, Japanese companies were very successful in 2.5 inch drives, such as IBM Japan, Toshiba, Hitachi etc, dominated the manufacturing of 2.5 inch drives. Because of the extremely fierce competition, Seagate did not devote lots of energy into the 2.5 inch business, when 5.25 inch and 3.5 inch were very healthy businesses and provide large amounts of profits. You should have a portfolio of investment, and take care of the financial returns.

When 2.5 inch began to prosper in the CE market ever since 2000, Seagate lost no momentum to work hard on the 2.5 inch drive business and came out with new technologies and products. They continued to make strategic investments in Singapore by leveraging established infrastructure and tapping significant technological and human capital this island-nation has to offer. Seagate's overall development milestones in 2.5 inch drives are summarized in Table 7.

Table 7 Seagate's development activities of 2.5 inch drives

What Seagate has done	**Why they made these decisions**
In 1991, shipment of 2.5 inch drive to Notebook market	
In 1992, first introduced shock-sensing technology for 2.5 inch disc drives	
In 1996, Seagate acquired Conner Peripherals	The 2.5 inch drive technology was not good enough for future competition. Seagate acquired CP for its engineering talents. This was a major consolidation, to increase the market shares.
In 1997, Seagate decided to change from technology follower to leader	With shorter product life cycle (areal density increase at rate of 100%, cycle of 6 months), follower strategy didn't work well in 2.5 inch drive biz; CTO Tom Porter believed that the only way to compete in the 2.5 inch business at that time was to have the leading technology
Cancelled all work on 2.5 inch drives at Seagate and used the money instead to invest in Advanced Concepts Lab (ACL) and Seagate Research (SR)	In order to be technology leader, ACL was devoted to look at 2-4 years ahead; SR has the mission to look at 5-10 years in the future
In June 2003, Seagate entered notebook market with Momentus 2.5 inch drive	When 2.5 inch drives started to take off since 2000 in Consumer Electronics Market, Laptop markets and even enterprise hard disk drive application, Seagate tried its best to develop the most advanced 2.5 inch drives with new technologies.
In 2004, announced Savvio, the industry's first 2.5 inch enterprise disc drive	
In 2005, introduced perpendicular recording 2.5 inch drive	

The next generation form factor Seagate has actively invested and promoted was 1 inch drive for handheld consumer electronic devices. According to Bill Watkins, the President and CEO,

Seagate had investment plans for a new S$200 million media plant to design, develop and manufacture its 1-inch drive for global consumption. In addition to this facility, the company also operates a factory that develops small portable storage devices and produces the company's enterprise and mobile storage products.

The first 1-inch hard disk drive with a capacity of 5GB in 2004 marked Seagate's foray into the growing market for handheld consumer electronics devices. It was just one of a dozen new product lines launched in an attempt to expand beyond its established base in home and enterprise computing. This was the only R&D carried out in US, the design was in Singapore and manufacturing in China. Seagate was hoping it would reclaim the reputation of 1-inch drives, which have been accused of being too fragile for mobile devices and not offering enough capacity for their price. Seagate developed the heavy-invested ST1 platform for many other handheld entertainment devices such as PDAs and MP3.

However, the largest customer of Microdrives such as 1.8 inch, 1.3 inch and 1 inch in handheld devices was Apple, which switched Ipod storage medium from microdrives to flash memory when it introduced Ipod Nano in 2005. The switch caused extremely serious impacts on small form factor makers, and Seagate also suffered from the loss of 1 inch drive oversupply.

Stage VI—Confidence in future HDD market—Hybrid HDD--2007 on wards

Will the Flash memory disrupt hard disk drives in the future? This is the most heated and debatable question that concerns the hard disk drive producers, particularly the leader, Seagate. Seagate sincerely believes the future of hard disk drives, and they consider flash would even increase the growth of hard disk drives. Most flash-based handhelds get their contents from PCs with high capacity Hard disk drives, and those contents are served by content aggregators with massive hard disk drive content servers, such as Google, Yahoo, and iTunes. In addition, hand-held contents also increase the need for backup, which usually fulfilled on a local hard disk drive. Compare performances and cost of Flash versus HDD (Table 8), Flash is likely to be used in combination with HDDs, and stand-along in some specific compute niche applications. It is very unlikely to disrupt HDDs in mainstream computer applications.

Table 8 Performances and Cost comparison between Flash and HDD

Mainstream PC application in 2007	**Flash**	**Hard Disk Drives**	**Comparison**
Capacity/cost	low	high	Flash has a much lower capacity cost ratio than that of HDD
Size	54 mm x 8 mm	70 mm x 9.5 mm	Size does not matter, keyboard, optical, battery and fans determine size before storage
Power : Battery Life	X+10~20 mins	2.5 inch HDD, X mins	Very incremental improvement
Reliability (node outage possibility)	1.8	1	80% more likely to create a node outage
Write	Problems of write cycle integrity	No write limit	Unreliable
Application	Some handheld CE devices	Some handheld devices and mainstream computer applications	

Although the disruption is very unlikely to happen in the near future, Seagate is very willing to explore any new technologies and products pertaining to information storage. They actively participated in the competition area of flash memory. What they pay attention to is the balanced portfolio of bets, rather than limiting themselves to the only financial pay-off. Seagate launched its first Hybrid Hard disk drive in late 2006 and new Flash memory in late 2007 (Figure 4).

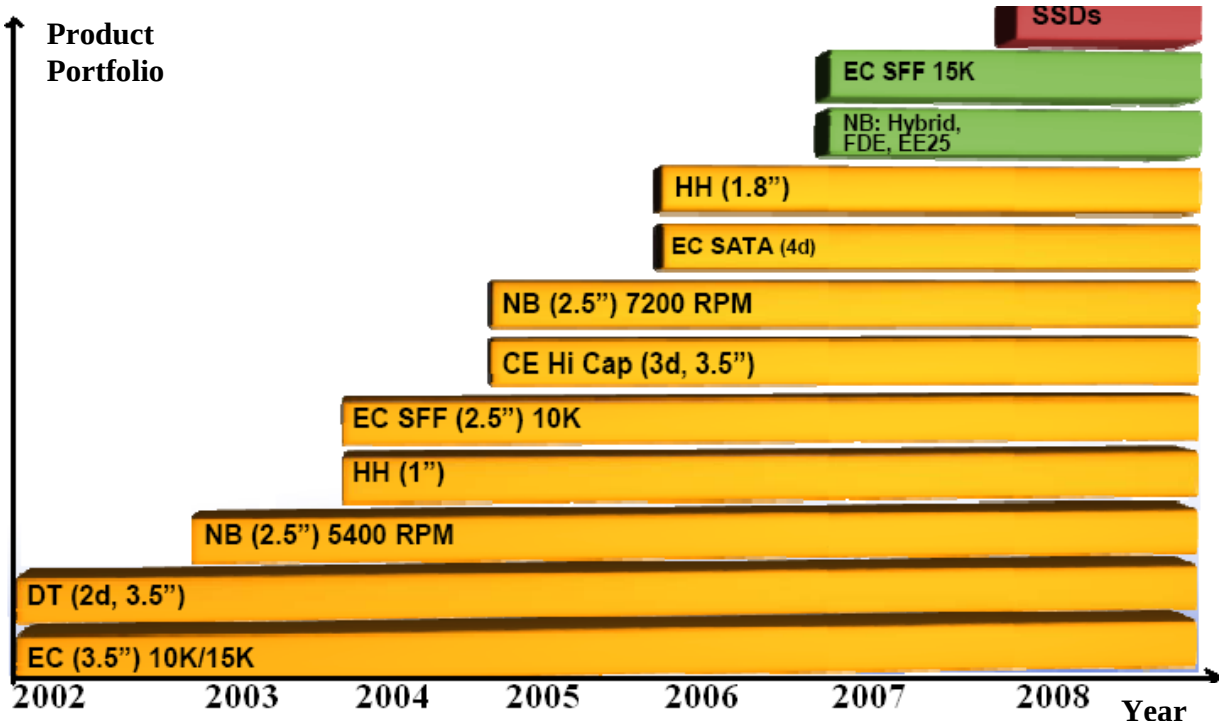


Figure 4 Expanded product portfolio of Seagate along the years

Seagate prevent any potential disruption and secured its leading position by releasing all form factor HDDs in use and the emerging storage products such as Hybrid HDD and Flash memory to satisfy 100% customer requirements. It's not the question of what and when the new form factor would disrupt the previous generation any more, it is the balance among supply of all product ranges and demand of various market segments.

Appendix I-- Interview of Prof Mark Kryder, Ex-Head of Seagate Research

CC : Prof CC Hang
MK : Prof Mark Kryder
Date: 29 Nov 2007 and 27 Dec 2007

CC: Seagate did not develop 3.5 inch drives initially and some ex-Seagate people started Conner Peripherals to make 3.5 inch drives for the lap-top computer vendors. 3.5 inch drives took off and eventually Seagate had to reverse its strategy and bought Conner Peripherals. How and why initially the 3.5 inch drive idea was rejected by Seagate: Could the following be the main reasons?

a. 3.5 inch drives were not needed by its minicomputer customers
b. Most R&D engineers looked down upon the 3.5 inch design
c. Financially not attractive enough for Seagate to pursue
d. Limitation of financial resources
e. Avoidance of cannibalization
f. Strict top-down approach i.e. the 3.5 inch project was not listed in roadmap or 5 year plan – hence not keen to support the project

Had this experience affected the subsequent R&D and innovation strategy of Seagate? Did you change the R&D project selection process to facilitate such innovations?

MK: I joined Seagate in 1998, well after they were making 3.5 inch drives and well after they purchased Conner Peripherals. Hence, I really have no direct knowledge of how the development of 3.5 inch drives affected Seagate's R&D and innovation strategy. As far as I understand, however, it did not have a dramatic effect.

What did have an effect was the acceleration in the areal density growth rate of hard drives in the late 90's. Up until about 1991 the areal density growth rate was about 25% per year, which meant that a product lasted about 2 years. In 1991, IBM announced that henceforth the areal density growth rate would be 60% per year. This initially shocked the industry, but then competition actually caused the areal density growth rate to increase to over 100% per year. With an areal density growth rate of 100% per year, a product had to be replaced in about 6 months. With a product life cycle of two years, as in the 80's, if a company were a few months late in introducing a new product, but produced a lower cost/better product, it could do very well on the backend of the product cycle. Hence, because Seagate had low-cost manufacturing capability, its close-follower strategy was quite successful and the company grew to become the largest maker of disk drives. However, with an areal density growth rate of 100% and a product life-cycle of 6 months, if you were 2-3 months late to market, the OEM's who were your customers weren't interested in even qualifying your product, because they were already looking ahead to the next product. This was the situation in 1997 when Seagate decided to change their strategy from being a close follower on technology to being the technology leader. At that time, they hired Tom Porter to be CTO and Tom set about to make Seagate a technology leader. Tom asked Nigel Macleod to start the Advanced Concepts Laboratory, which had the mission of looking 2-5 years out and subsequently hired me to start Seagate Research, with the mission of looking 4-10 years in the future. Prior to that, drive development projects in Seagate started about 2 years ahead of product shipment. Together, we focused a great amount of attention on developing advanced technology and moving it into Seagate products. In a matter of a few years, under Tom's leadership, Seagate became the technology leader in the industry.

CC: From a R&D/technology point of view, how challenging was the miniaturization effort to develop 3.5 inch drives from 5.25 inch drives, and then to 2.5 inch and 1.8 inch? One indication was the no. of new patents filed for the design/dev of the smaller drives -- any input on this?

MK: As I said above, I was not at Seagate during the transition from 5.25 inch to 3.5 inch. So, I have no knowledge of how challenging that was. With the close follower strategy and the short product life cycle Seagate was not doing well in the 2.5 inch business in 1997. Tom Porter

believed that the only way to compete in the 2.5 inch business at that time was to have the leading technology. Because Seagate was not a technology leader at that time, Tom decided to cancel all work on 2.5 inch drives at Seagate and use the money instead to invest in Advanced Concepts and Seagate Research. It took a few years for Seagate to become the technology leader, but once Seagate took over the lead in technology, they reentered the 2.5 inch drive business. This occurred just a few years ago. Doing that was a major focus for a certain subset of the drive development organization and was certainly a challenge for them, but Seagate had the technology to do it and it worked quite well, as Seagate today has a large and growing presence in the 2.5 inch drive business.

CC: The need for technology leadership is an important point not emphasized in the Disruptive Innovation literature. Can you please tell me more about Seagate Research?

MK: Seagate Research has roughly 100 PhD's working there. It is a very diverse group, coming from 24 different countries and 65 different universities, the last that I knew. The total number of scientists and engineers (PhD's and not) was about 130 the last that I knew. They were generating 50-100 patents per year and a similar number of publications. Seagate Research collaborates with universities all over the world including the Data Storage Institute in Singapore and the National University of Singapore.

CC: I am surprised that the 2.5 inch technology required such a large commitment in R&D. Can you please tell us more about this type of technology leadership which was not needed when transiting to and developing 3.5 inch from 5.25 inch technology?

MK: The transition from 5.25 inch drives to 3.5 inch drives did not require large changes in technology. Both form factors were used primarily for desktop PC's. As always, capacity would be an issue, but once the areal density capability was sufficient, then the transition should have been able to be made fairly easily, and given that the 5.25 inch drives were a sizable portion of the PC, the OEM's probably desired the smaller form factor. Success with 2.5 inch products, however, required high areal density, shock resistance, and excellent reliability, as they were used almost exclusively in laptops when they were first introduced. 2.5 inch drives used glass

instead of aluminum disks and the heads were ramp-loaded and parked off the disk when the disk was not spinning. To be successful, you needed to have high areal density, as well as these other characteristics. Hence the transition to 2.5 inch drives was in some respects more challenging than the transition to 3.5 inch drives. Nevertheless, areal density was really king, as there was not a large market for low capacity drives. Users wanted to be able to do just about everything on their laptop that they could do on their desktop. IBM had over 60% of the business and their drives were typically excellent in all these respects. If you could only produce a low capacity drive, you were not going to be profitable. Seagate and a lot of other companies experienced that. Bottom line is that, as Seagate experienced it, you had to have technology leadership to crack into the 2.5 inch business profitably.

Today, on the other hand, the 2.5 inch business is a much larger business than it was 5-10 years ago, and there is a lot larger variety in the product offerings. The laptop is overtaking the desktop PC in popularity. Consequently, entry into the 2.5 inch business does not depend solely upon leading edge technology, and there is a place for a low-cost 2.5 inch product.

The team that developed the 2.5 inch drive in Seagate was led by Nigel Macleod, who had previously led Seagate's Advanced Concepts Laboratory, which was responsible for technologies 2-5 years ahead of product. It was a somewhat unique development effort for Seagate at that time, as all previous drive development projects had been developed by a dedicated team in one location. To do the 2.5 inch drive development a special team which involved engineers from both Colorado and Minnesota worked together. When the project was begun, Seagate already had become the areal density leader in longitudinal recording. So, the task was really to do the mechanical integration.

Seagate's ability to break into the 2.5 inch business was thus not primarily due to efforts in research in Pittsburgh. It is true that Research led the original effort to achieve 100 Gbpsi, but the work done in Research was primarily on perpendicular recording and that did not appear in Seagate products until 2006, considerably later than when Seagate re-entered the 2.5 inch drive business. Research was focused on making perpendicular recording a reality until early 2002, when the development divisions of Seagate began to work on perpendicular recording

technology. It became product in 2006. Although Research stayed involved in perpendicular recording, it ratcheted its goals up to 10 Tbpsi once the development teams became involved and also aggressively pursued programs on Heat Assisted Magnetic Recording and Bit Patterned Media, which are expected to be needed beyond 1 Tbpsi.

CC: What about 1.8 inch and 1 inch technology?

MK: With regard to 1.8 inch technology, no there is not a huge gap between what is needed for it and what is needed for 2.5 inch drives. There was similarly no huge difference in technology for 1 inch drives. The heads and media used for the 1 inch drives that were put into the early iPods were basically the same as for larger form factor drives. Again, however, Seagate already had the technology lead when it was decided to enter that market, which made it successful in entering the market quickly to obtain a large market share.

CC: Do you see 2.5 and 1.8 inch replacing 3.5 inch as the dominant design within the next 5 to 10 years?

MK: That seems to be the way things are heading. Even enterprise drives today are shifting to 2.5 inch form factor. If areal density continues to increase, then this is very likely to be what happens.

CC: Do you think that the USB flash drive, which has successfully blocked the business of 1 inch drive in portable consumer electronics products, will eventually compete with 1.8 and 2.5 inch drives a few years from now? (Note: Seagate seems to be quite well versed with the flash memory and has recently launched the hybrid hard disk/flash drive products.)

MK: My perspective is somewhat different than what you seem to be implying. There have always been non-volatile memory technologies like flash that offered a lower unit cost than hard drives and hence were used in applications that did not require the capacity of a hard drive. Because the areal density of hard drives goes up over time, the minimum capacity of a hard drive also goes up over time. Up until the introduction of 1 inch drives in the iPod, hard disk drives

had been used almost exclusively for computing applications. What was amazing was that hard drives made in a 1 inch form factor enabled an entire new industry (digital audio players) in a space that had always been occupied by solid state memory devices like flash. However, it was inevitable that flash would retake that space, since the capacity required to digitize 1000 songs is fixed and hard drive capacity continuously moves upward.

I am very doubtful that flash will ever be able to compete with 2.5 inch hard drives and most likely not with 1.8 inch drives, because its cost per gigabyte is far higher than the cost per gigabyte in either of those form factors. Although the price of flash was dropping considerably faster than the price of hard drives a couple of years ago, the price of flash is not dropping nearly so quickly now. I believe this is because the flash makers are now manufacturing at large volumes and have reduced their profit margins about as much as they can afford to. In about 3 years flash will be approaching the 20 nm lithography node, where they acknowledge they have some very fundamental limits in their ability to scale their technology to higher densities. On the other hand, I feel quite comfortable in projecting continued increases in hard drive areal density for at least another decade. Unless flash is able to get around their fundamental scalability problems or another solid state technology with better scalability than flash appears, you might once again see hard drives even smaller than 1.8 inch.

CC: What is the overall R&D strategy of Seagate in preventing potential disruption of its business?

MK: I retired from Seagate in February, 2007. Hence, I am not able to describe what they are doing today. However I described above what Seagate did to become the technological leader in the industry and, although, there have been some changes to the technology strategy since then, Seagate Research, as far as I can tell, is still aggressively pursuing numerous advanced technologies that will likely lead the industry to areal densities approaching 50 Terabits/in^2, which is about 200 times the density of products today.

Appendix II-- Interview of Mr. Say Kwee Teck, VP Engineering and R&D Director Singapore

Title: Interview/Discussion at Seagate Technologies International, Singapore
Time: 3:30pm—4:30pm, December 21, 2007
Venue: Seagate, The Fleming, 59 Science Park Drive
Attendants: Seagate Tech Int'l, S'pore: Mr. Say Kwee Teck (VP Engineering and R&D)
NUS: Prof. Hang Chang Chieh, Ms. Yu Dan

Contents:
S=Say Kwee Teck
H=Hang Chang Chieh

H: (who started to ask questions after introducing the research topic of Ms Yu Dan, and the academic theory of disruptive innovation.) One of the major reasons why the best managed companies could fail when confronted by the so-called disruptive innovation is that they listened too closely to and hence were locked-in by their existing customers. However, Seagate was an exception which lasted in 2 past disruptions in the Hard Disk Drive Industry, and is ready to face the next one. Can you please tell us what fundamentally differentiate Seagate from other large companies?

S: We are willing to explore new technologies and products. Anything pertaining to information storage, we would explore. For example, we invested many millions of dollars in the Data Storage Systems Center at Carnegie Mellon University, and we also have plenty of research collaborations with Research Institutes such as IMRE in Singapore. They would help us to quickly spot the potential opportunities in the Data Storage Industry. Although we are the leading company in Hard Disk Drive industry, we are eager to explore the area of flash memory instead of treating it as a threat. What we pay attention to is the balanced portfolio of bets, rather than limiting ourselves to the only definite financial pay-off. We are very willing to explore the Fuzzy Front End.

H: So the managers are driven by the visionary mindset and actively explore the future?

S: Yes, but we try to walk away from one man vision. We carefully structure the collective vision by extensive discussions among the senior managers, seeking advices from consultants, and inviting outside reviewers to review the bets. We believe the advices and analysis from outside could provide us different angles for our own data.

H: Do you adopt the scenario planning in Seagate?

S: Yes, we do. The senior managers periodically get together to make scenarios thinking, for example, what would happen if IBM bought company A. We are paranoid even when we are very successful in certain R&D projects or commercialization of new products, and we perceive that something else should be done to make it better or more. We never feel satisfied and always look for the future.

H: Regarding the senior managers, in Seagate, how often have changes taken place on the positions of them?

S: Seagate has a very stable management team over the last 10-15 years. The current team has started since middle 1990s, and most of them came from well-established leading companies such as IBM. Seagate was privatized in 2000. Since then, the senior managers have assumed more responsibility and devoted more commitments to the future development of Seagate, even after it was relisted in the stock market. The managers are very far sighted as they are encouraged and expected to contribute to secure the future of the company. Much effort was expended to promote team spirits and networking.

H: Seagate Singapore has successfully developed the new product of 1 inch drive -- why was the R&D done with no directive from the US HQ?

S: We are very flexible here. Sometimes, we play for fun, and take a bet for the future. For example, in the development of 1 inch drive, we did not have a clear application of the 1 inch drive when we began our R&D on this project. It may not take off so soon, but with the fast progress of technological innovation, 1 inch may become the future in the next few years. In terms of the R&D activities, the Corporate R&D is focusing on the basic and high level research such as areal density and laser technology etc. But they are not clear what are the exact products or applications for the new technologies. In Singapore, what we do is trying to find a niche, supporting technologies applicable in products, the solutions or products for customers. The research in Singapore should not compete with US; instead it should complement the technological achievements of corporate research in US.

H: If we go back to the discussion of 2.5 inch drive, according to the literature, 2.5 inch was developed and deployed within the same nested architectural system as the 3.5 inch product and Seagate was catching up very quickly in the previous wave of 3.5 inch drive. So why Seagate initially did not have the technologies required for 2.5 inch drive?

S: From 3.5 inch to 2.5 inch, it was in fact very difficult. The minor forces/disturbances became much magnified when we scaled down the dimension. Yet the tolerance could not be scaled down. Besides, you have to change/educate the suppliers, factories, and sometimes reinvent several modules.

H: What was the initial market application for 2.5 inch drive?

S: When the 2.5 inch was born, it was all used in notebook computers.

H: What are the reasons Seagate acquired Conner Peripherals back in 1996?

S: Conner Peripherals was a serious competitor and had developed leading technologies in 2.5 inch drives. CP has capable engineers, good managers, opulent resources… everything is available there. Hence, it was advantageous to us in buying it over.

H: As far as we know, Seagate's CTO at that time, Mr. Tom Porter believed that the only way to compete in the 2.5" business at that time was to possess the leading technology. So he hired Prof Mark Kryder to address this problem by starting Seagate Research in 1998. Why was he not satisfied with the technologies gain from CP?

S: Yes, the 2.5 inch drive technology at that time was not good enough for future competition. Tom brought in Prof Kryder to bring a new perspective of researchers (from top companies such as IBM and top universities) and bring a new culture here. This is also the way we could find more talented graduates from universities. Seagate Research will think of future opportunities and challenges beyond 5 years. The need to think long term has been practiced at all levels. Hence even in S'pore where our key role is in new product development, we allocate at least 10% of our resources to pursue advanced concepts and research work.

Appendix III-- Interview of Mr. Djohni Chandra,

Executive Director, Singapore

Title: Interview/Discussion at Seagate Technologies International, Singapore

Time: 2pm—3 pm, Jan 21, 2008

Venue: Seagate, The Fleming, 63 Science Park Drive

Attendants: Seagate Tech Int'l, S'pore: Mr. Djohni Chandra (Executive Director)

NUS: Ms. Yu Dan

Questions:

A. Development of 2.5 inch drive

A1, The following table lists the major activities Seagate has done on the 2.5 inch drive (I may miss some milestones, sorry). Would you please kindly review and introduce when and under what condition, Seagate decided to pursue the R&D on 2.5 inch drive? How was it going on?

What Seagate has done	**Why they made these decisions**
In 1991, shipment of 2.5 inch drive to Notebook market	
In 1992, first introduced shock-sensing technology for 2.5 inch disc drives	
In 1996, Seagate acquired Conner Peripherals	The 2.5 inch drive technology was not good enough for future competition. Seagate acquired CP for its engineering talents. This is a major consolidation, to increase the market shares.
In 1997, Seagate decided to change from technology follower to leader	With shorter product life cycle (areal density increase at rate of 100%, cycle of 6 months), follower strategy didn't work well in 2.5 inch drive biz; CTO Tom Porter believed that the only way to compete in the 2.5 inch business at that time was to have the leading technology

Cancel all work on 2.5 inch drives at Seagate and use the money instead to invest in Advanced Concepts Lab (ACL) and Seagate Research (SR)	In order to be technology leader, ACL is devoted to look at 2-4 years ahead; SR has the mission to look at 5-10 years in the future
In June 2003, Seagate entered notebook market with Momentus 2.5 inch drive	
In 2004, announced Savvio, the industry's first 2.5 inch enterprise disc drive	
In 2005, introduced perpendicular recording 2.5 inch drive	

You need to understand the technological background of the evolution of HDD industry. From 5.25 to 3.5, or from 3.5 to 2.5 inch drives, capacity is the key that each generation is working on, however, other closely related components are also very important. When the spindle spins faster, all the problems like vibration, heat generation should be solved before the adoption of a new form factor. In addition, it needs the high processing CPU and channels to cooperate. This is the reason that the initial experiments by Quantum on the research of 5.25 inch drives failed.

When you look at the market side, customers require high quality in various attributes such as capacity, power consumption, weight, size, heat generation, mechanical robustness, and noises of the motor, data transfer speed, shock resistance…. When you see when customers demand more on the less power consumption, lighter weight, smaller size which favor the small form factor, you would begin to heavily invested in the small form factor business.

We were not very active in the 1990s on the development of 2.5 inch drive because the profits margins were too limited. At that time, portable PC was not a large market segment, it is not until this year that mobile PCs have shipments that surpass the desktop PCs. Hence, the 2.5 inch drives, only in Portable PC application, has a very limited market shares compared with other form factors. Furthermore, Japanese companies were very successful in 2.5 inch drives, such as

IBM Japan, Toshiba, Hitachi etc, dominated the manufacturing of 2.5 inch drives. Because of the extremely fierce competition, Seagate did not devote lots of energy into the 2.5" business, when 5.25 and 3.5 were very healthy businesses and provide large amounts of profits. You should have a portfolio of investment, and take care of the financial returns.

When 2.5" began to prosper in the CE market recent years, we lost no momentum to work hard on the 2.5 inch drive business and came out with new technologies and products. Who are the leading players in 2.5 inch business now? (Y: Because 2.5 inch has been used in all the applications and has a promising future in CE market, all the big guys have come in such as Seagate, WD..) Yes, everyone, because it has promising future! So you can see how the companies respond to industrial change. It was not Seagate; the successful players have the similar decision when industrial change took place.

B. Prediction of replacement of 2.5 inch drive to 3.5 inch drive in Portable application, Desktop application and Enterprise application. (See Figure A, B and C.)

When you look at the applications of HDDs, previously it was only used for computing in computer industry, this industry is very mature now, you know how the major trend how technology will evolve, what are the customers' requirements as I said, capacity, power consumption etc. The replacement of small factors to the large factors is natural. However, in CE market, the game is just beginning. This time we collaborate with the giants in CE market, for example, Apple, to create the future market. We think miniaturization is the key. (yes, but when the flash memory come, how could you secure your business?) Yes, we do face the threat from flash memory, particularly in the small form factors. However, the cost of HDD is much cheaper than the Flash memory. And now you can get 1 inch drive of 120GB, the capacity is also very high.

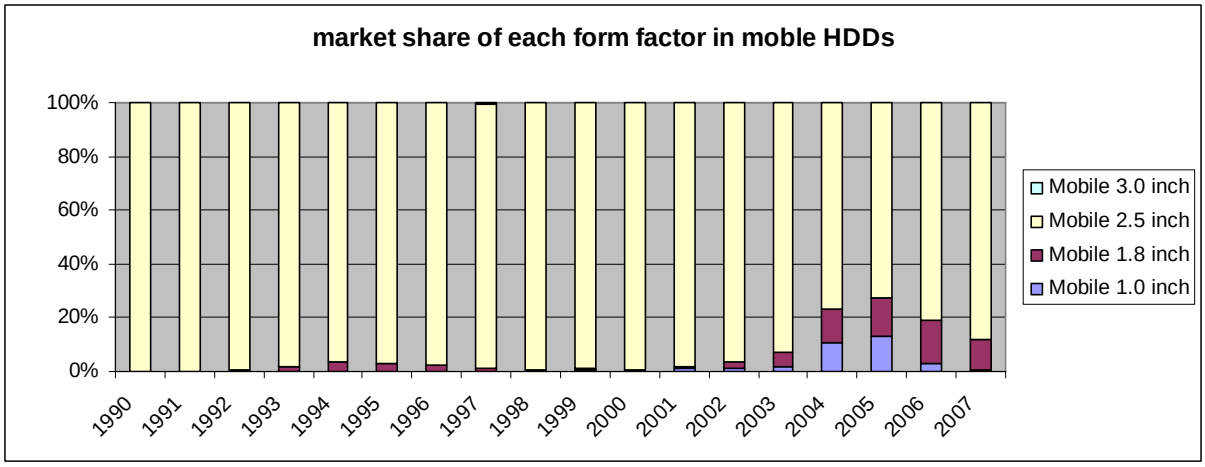


Figure A Market shares of different form factors in Mobile application

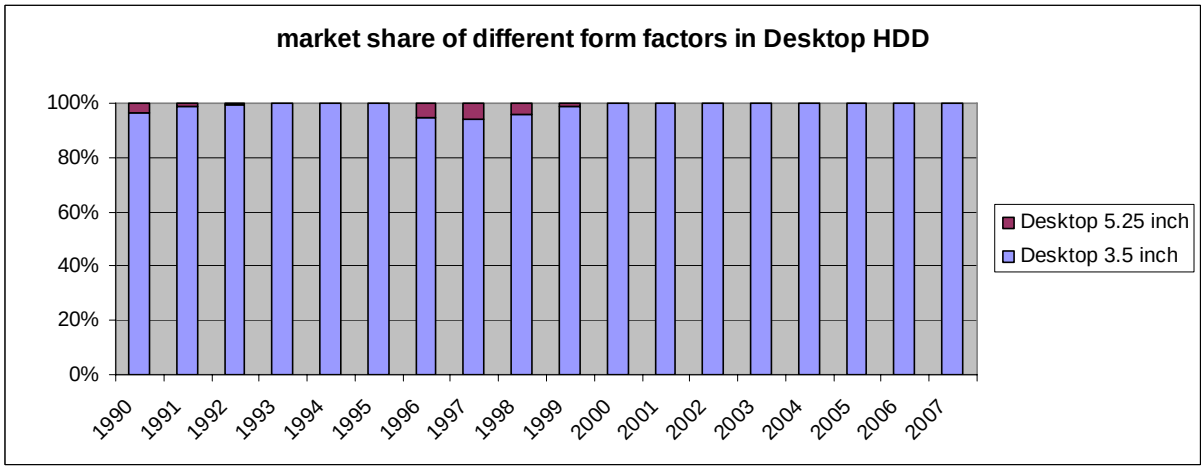


Figure B Market shares of different form factors in Desktop application

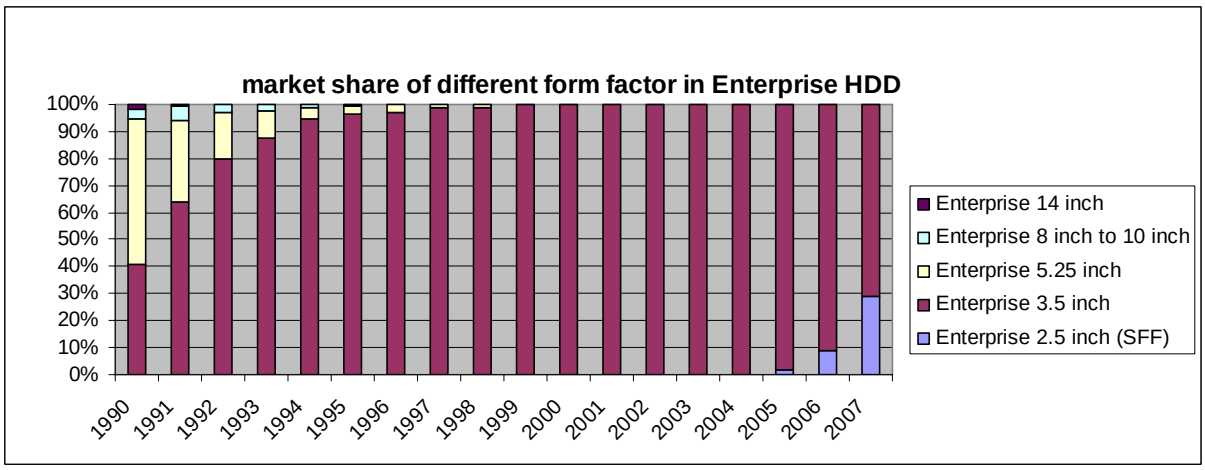


Figure C Market shares of different form factors in Enterprise application

B1, As shown in Figure D, do you think the curves approximately reflect (Year 2005-2007) and project (2008-2011) the situation of capacity provided and demanded in **desktop market**? Do you think the 2.5” would replace 3.5” in desktop application in the near future?

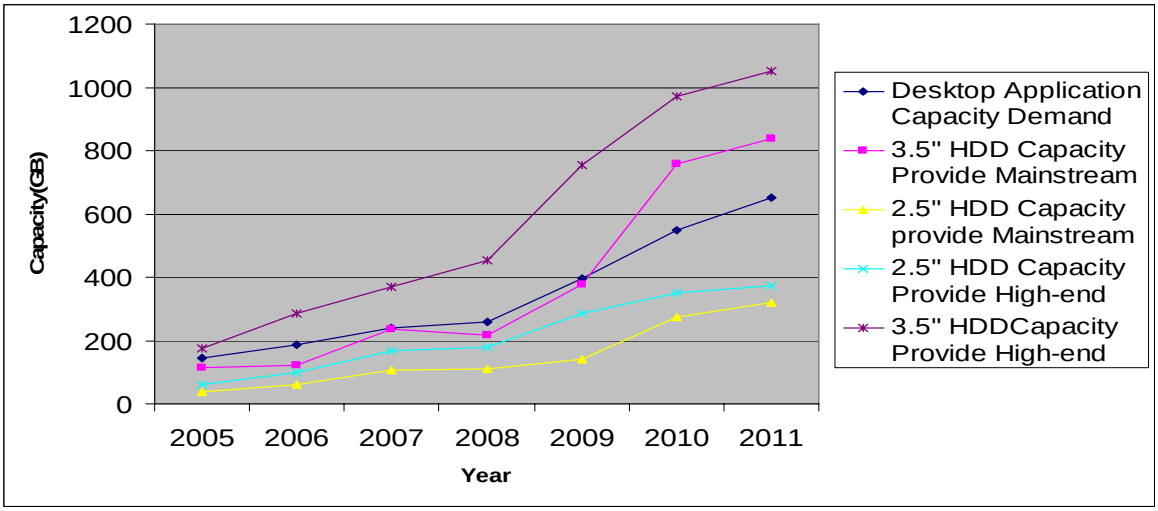


Figure D Capacity supply and demand for desktop application

It could not happen so soon. The capacity is still the key and 2.5 inch drives so far could not satisfy the desktops needs, and it could not compete with 3.5 inch in capacity. In the case of slim desktops, yes, 2.5 inch drive has its possibility. But for the power hungry desktop PCs or Servers, it could not. It’s also the problem of mechanical robustness.

B2, As shown in Figure E, do you think the curves approximately reflect (2005-2007) and project (2008-2011) the situation of capacity provided and demanded in **Mobile computing market**? Do you think the 1.8” would replace 2.5” in portable PC application in the near future?

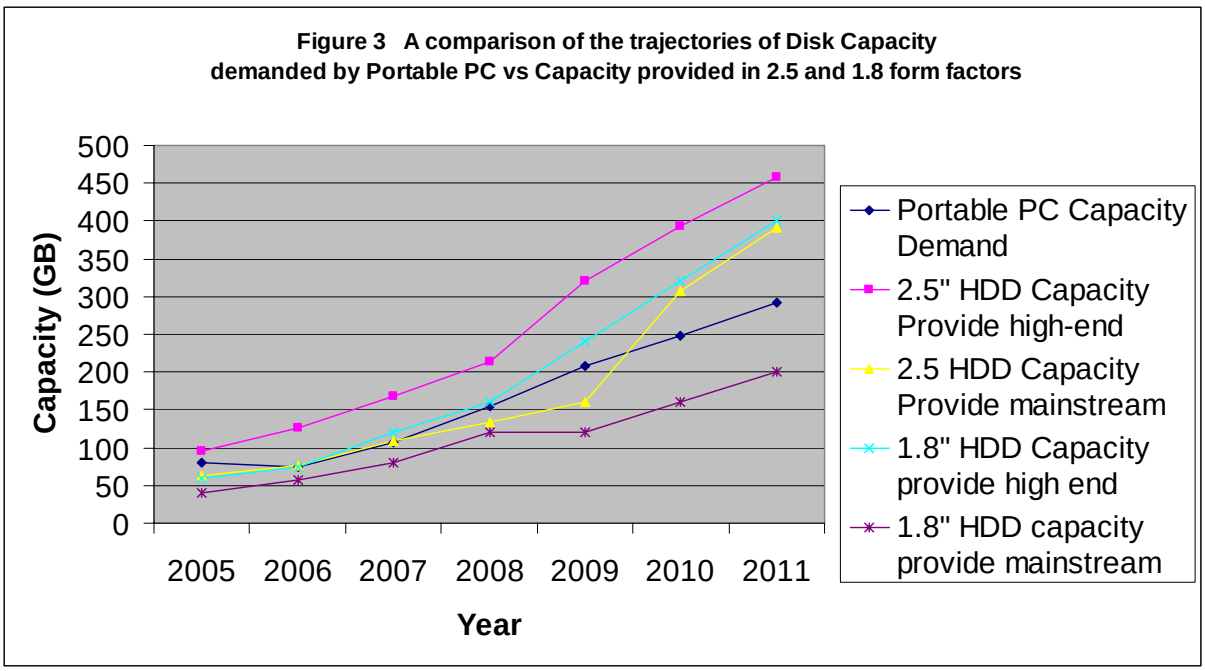


Figure E Capacity supply and demand for Portable PC application

Yes, the new Apple Inotebook has adopted 1.8 inch drive.

B3, As shown in Figure F, do you think the curves approximately reflect (2005-2007) and project (2008-2011) the situation of capacity provided and demanded in **enterprise storage market**? Do you think the 2.5" would replace 3.5" in this application in the near future?

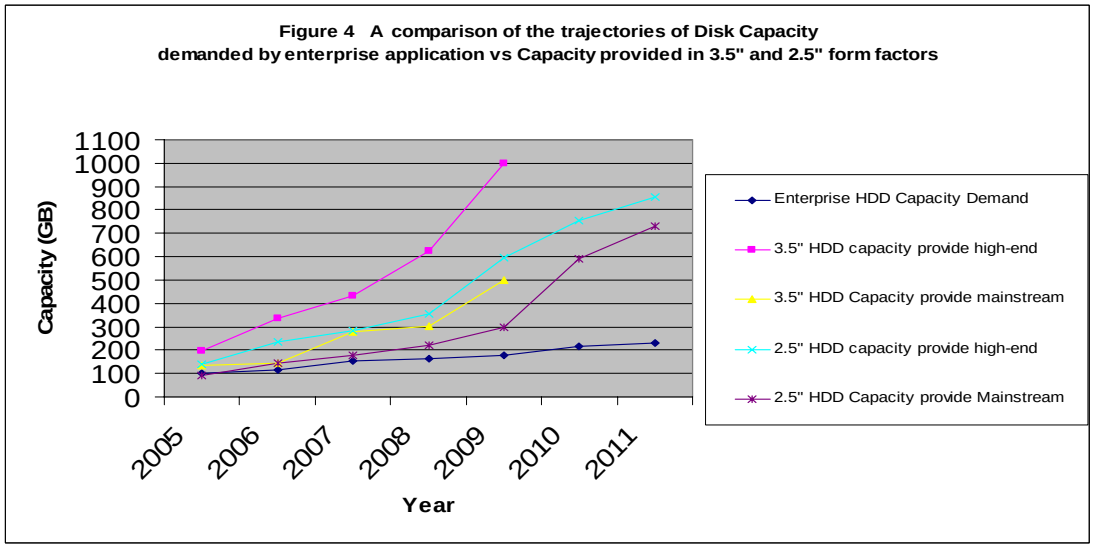


Figure F Capacity supply and demand for Enterprise PC application

Yes, it seems to be.

B4, As shown in Table I, different form factors started to ship in CE market since 2003. Before 2002, 3.5 inch drive was no longer applied in Portable PCs. Hence, can I assume that since the initial introduction to notebook PCs in 1989, the 2.5 inch drive was consistently used in Portable PCs and gradually replaced 3.5 inch drive in this market before 2002?

Table I Shipments of different form factors in various applications in 2006

Actual data						***Projected Data***				
Application	2002	2003	2004	2005	2006	*2007*	*2008*	*2009*	*2010*	*2011*
65mm--75mm Market (2.5 inch), by Application, Units (M)										
Enterprise	10.93	13.92	18.9	23.34	31.8	*45.45*	*69.35*	*78.9*	*81.05*	*85.95*
Desktop	0.81	0.13	0	0.74	1.38	*1.83*	*1.15*	*0.8*	*0.7*	*0.4*
Portable	55.42	73.54	84.62	128.52	188.35	*220.4*	*231.05*	*262.4*	*302.4*	*335.45*
CE	0	1.74	4.37	7.66	21.24	*32.7*	*35.85*	*37.45*	*39.35*	*46.25*
Total Units	67.16	89.33	107.89	160.26	242.77	*300.38*	*337.4*	*379.55*	*423.5*	*468.05*
95mm Market (3.5 inch), by Application, Units (M)										
Enterprise	4.07	0	0	0	0	*0*	*0*	*0*	*0*	*0*
Desktop	221.02	267.17	259.41	347.4	395.98	*414.25*	*424.25*	*437.95*	*446.8*	*472.75*
Portable	0	0	0	0	0	*0*	*0*	*0*	*0*	
CE	0	15.1	4.37	36.67	65.72	*84.05*	*132.65*	*205.65*	*220.55*	*224.55*
Total Units	225.09	282.27	263.78	384.07	461.7	*498.3*	*556.9*	*643.6*	*667.35*	*697.3*
84mm Market (3.5 inch), by Application, Units (M)										
Enterprise	42.73	37.85	45.52	38.51	39.29	*19.7*	*4.95*	*1.1*	*0*	*0*
Desktop	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*
Portable	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*
CE	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*
Total Units	42.73	37.85	45.52	38.51	39.29	*19.7*	*4.95*	*1.1*	*0*	*0*
48mm Market (1.8 inch), by Application, Units (M)										
Enterprise	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*
Desktop	0	0	0	0	0	*0*	*0*	*0*	*0*	*0*
Portable	0.33	1.7	1.56	2.66	1.54	*3.95*	*12.35*	*18.75*	*35.2*	*37.05*
CE		3.4	10.83	19.05	31.79	*32.1*	*32.6*	*33.35*	*34.3*	*34.8*
Total Units	0.33	5.1	12.39	21.71	33.33	*36.05*	*44.95*	*52.1*	*69.5*	*71.85*

Yes, the 2.5 inch was consistently used in the portable PCs to replace 3.5 inch drives until the emergence of CE products.